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Shirata

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(54) **OPTICAL SENSOR FOR DETECTING LUBRICANT DETERIORATION**

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(30) **Foreign Application Priority Data**

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G01N 21/85 (2006.01)
G01N 21/27 (2006.01)
G01N 21/25 (2006.01)

(52) **U.S. Cl.**

CPC ***G01N 21/94*** (2013.01); ***G01N 21/27*** (2013.01); ***G01N 21/8507*** (2013.01); ***G01N 33/2888*** (2013.01); *G01N 21/251* (2013.01); *G01N 2201/02* (2013.01); *G01N 2201/062* (2013.01)

(58) **Field of Classification Search**

CPC G01N 33/28
USPC 356/70
See application file for complete search history.

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(57) **ABSTRACT**

A lubricant deterioration sensor mounted in a machine to detect deterioration of a lubricant of the machine, the sensor comprising a white LED for emanating white light, an RGB sensor that detects colors of received light, a clearance forming member in which an oil clearance for intrusion of the lubricant is formed, and a support member that supports the white LED, the RGB sensor, and the clearance forming member; and wherein the clearance forming member allows passage of the light emitted from the white LED, and the oil clearance is placed along an optical path from the white LED to the RGB sensor.

12 Claims, 11 Drawing Sheets

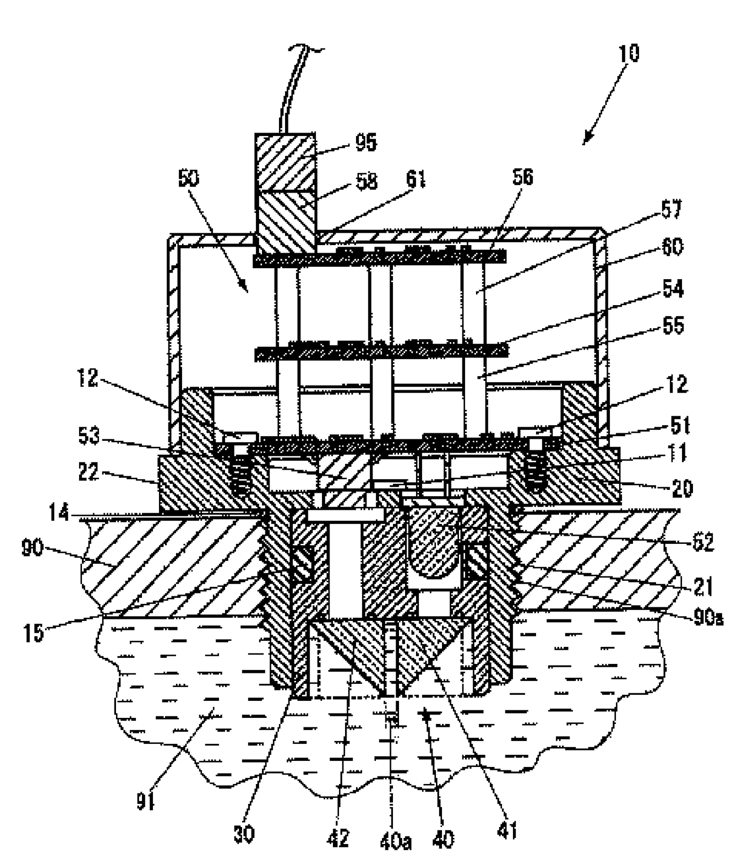

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Fig. 1

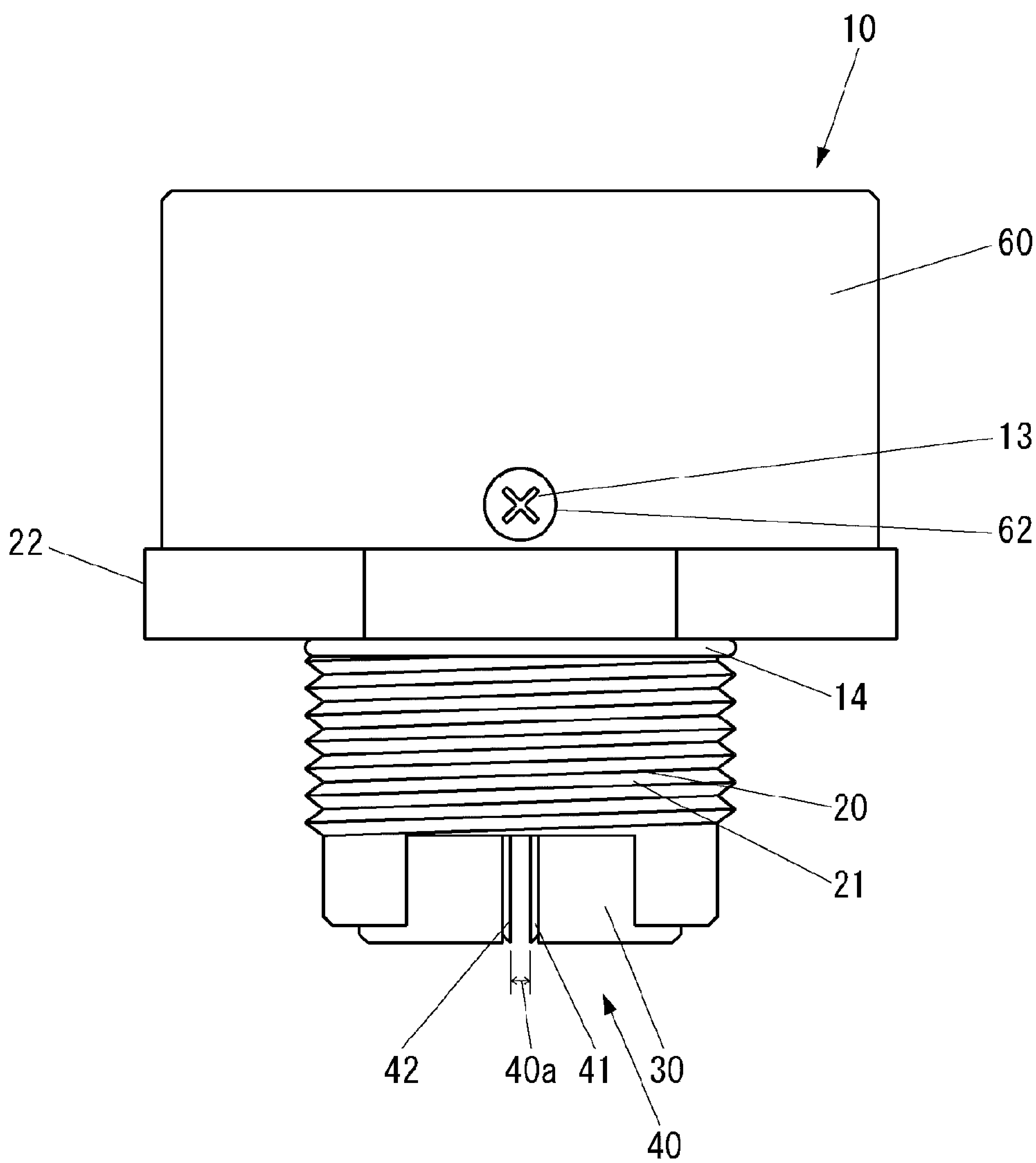

Fig. 2

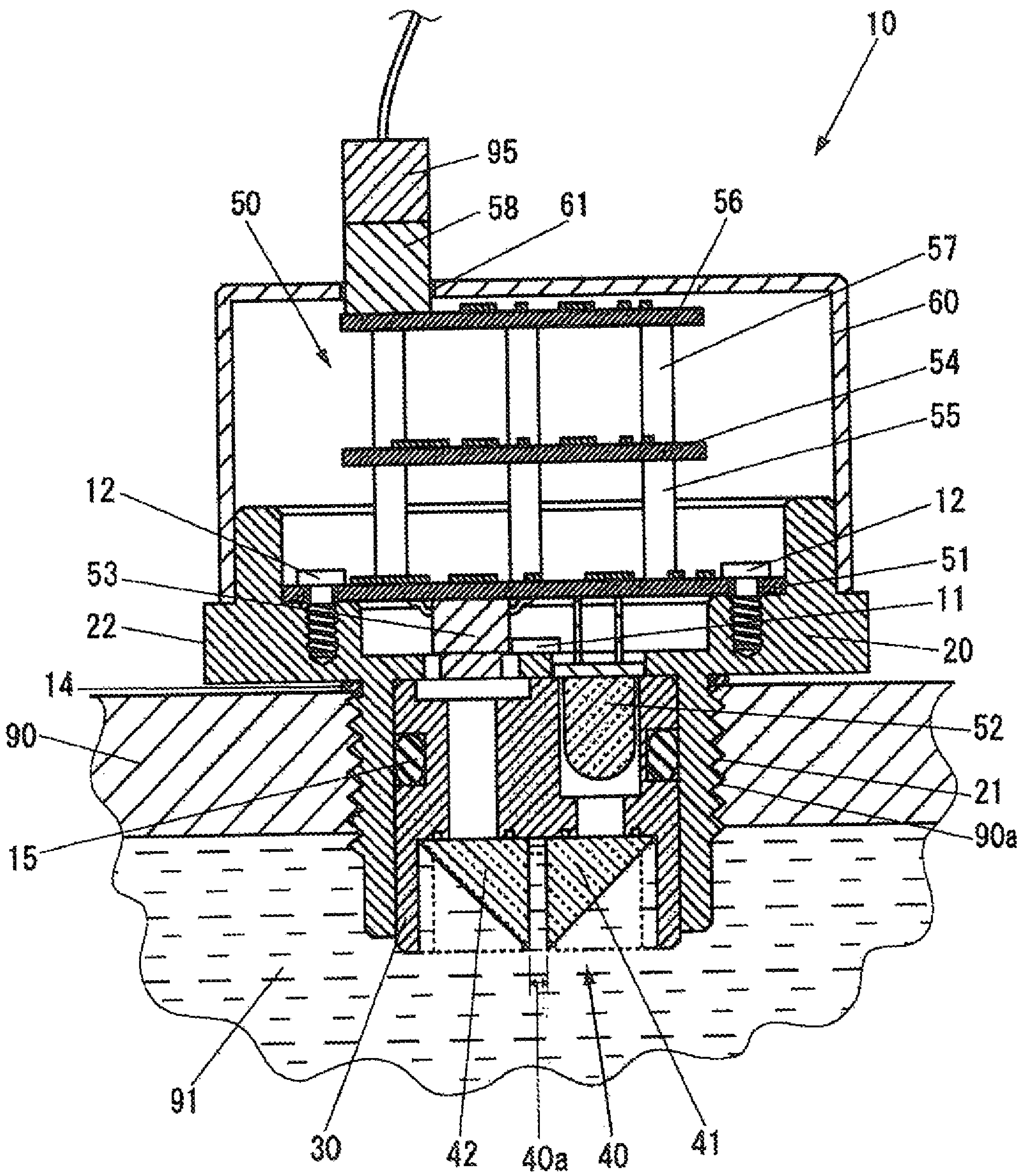
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Fig. 3A

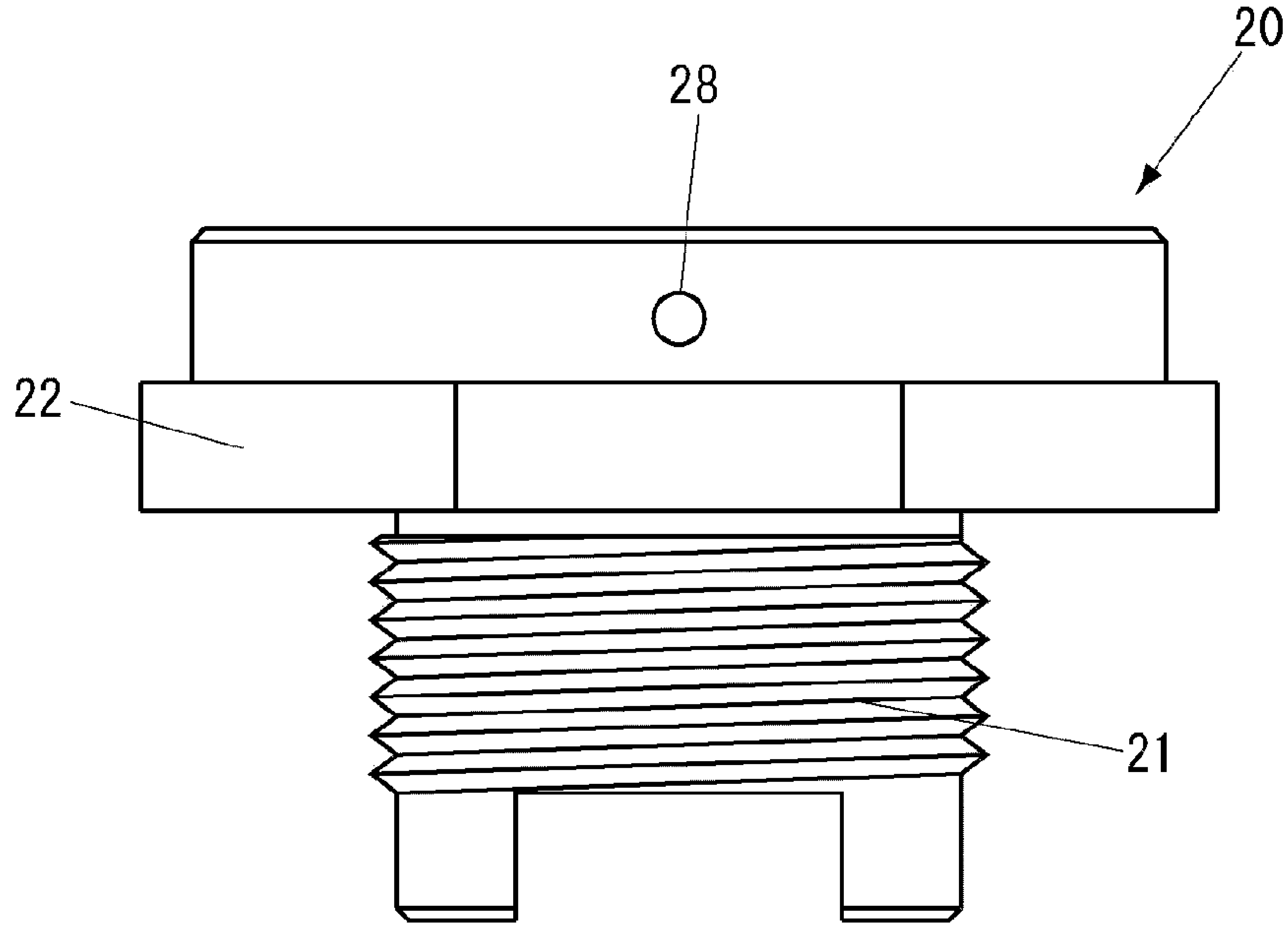

Fig. 3B

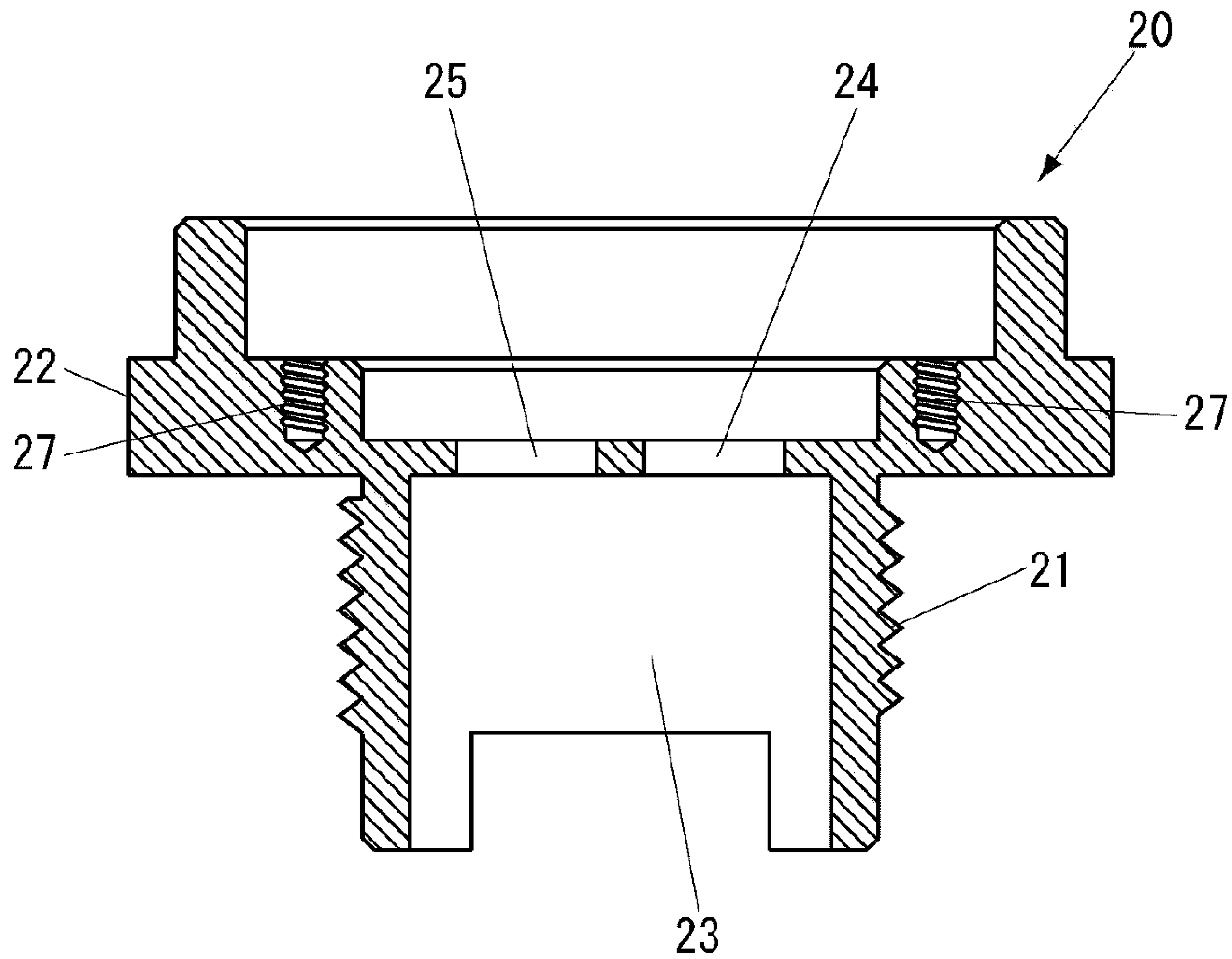

Fig. 4A

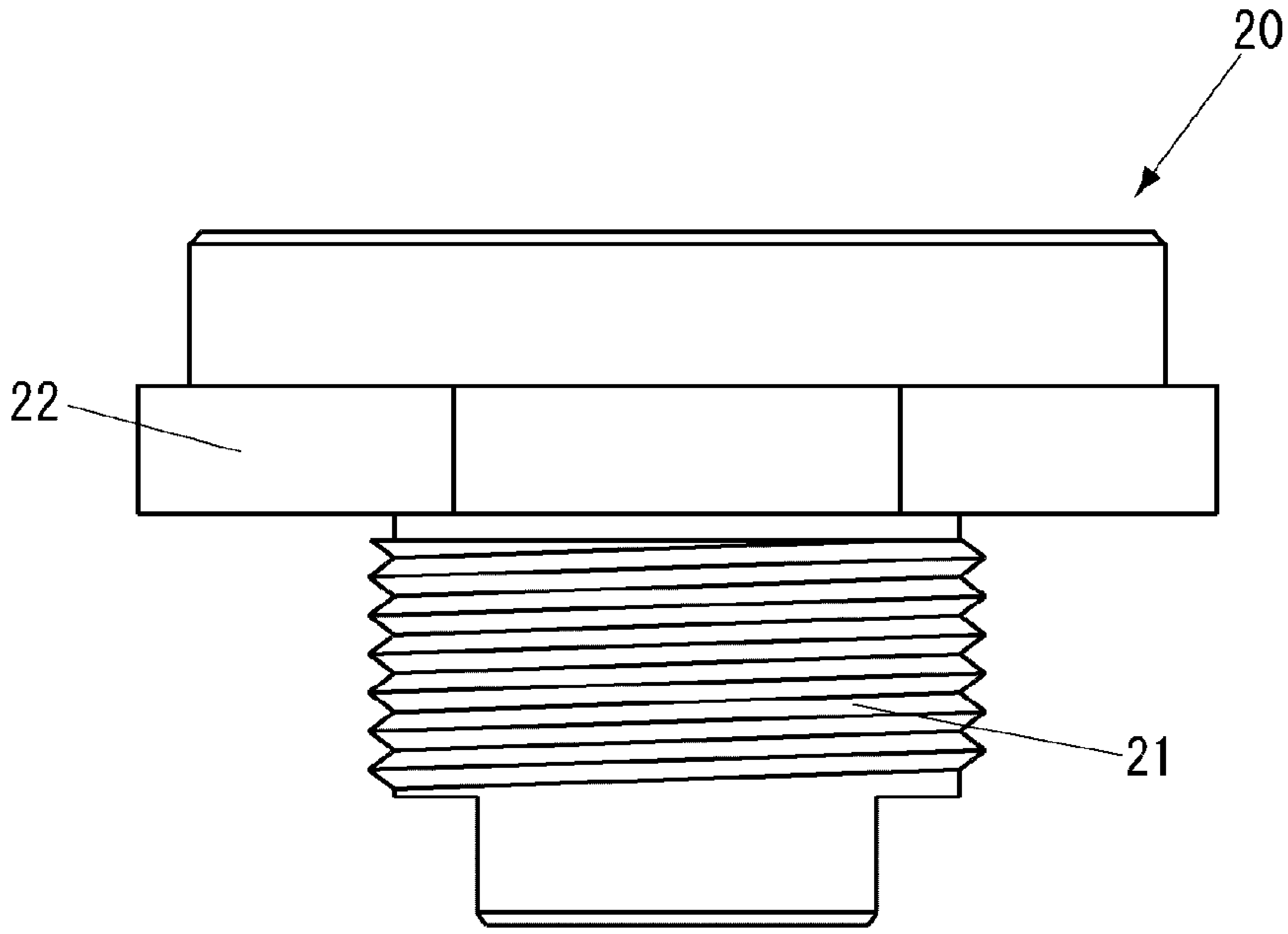

Fig. 4B

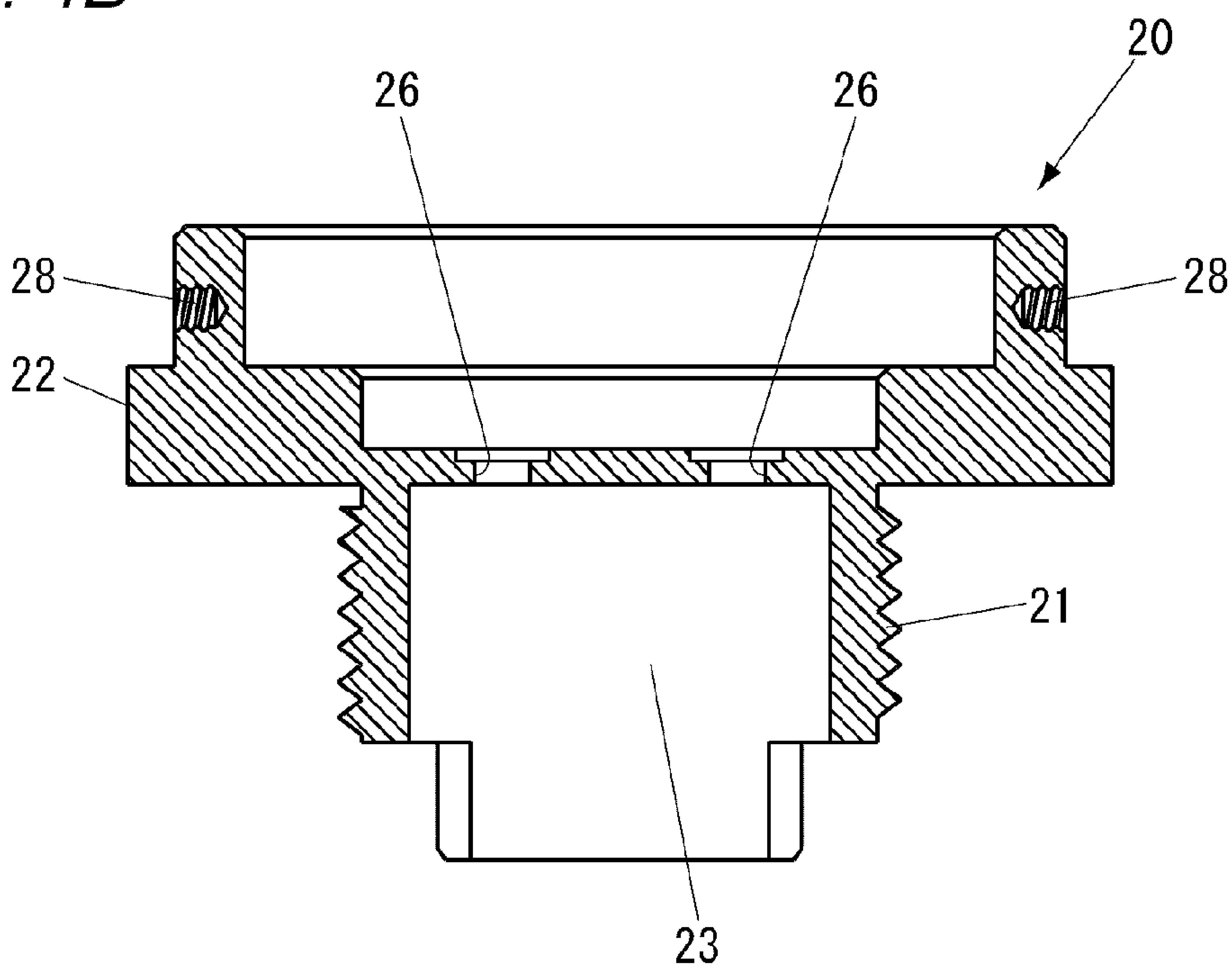

Fig. 5A

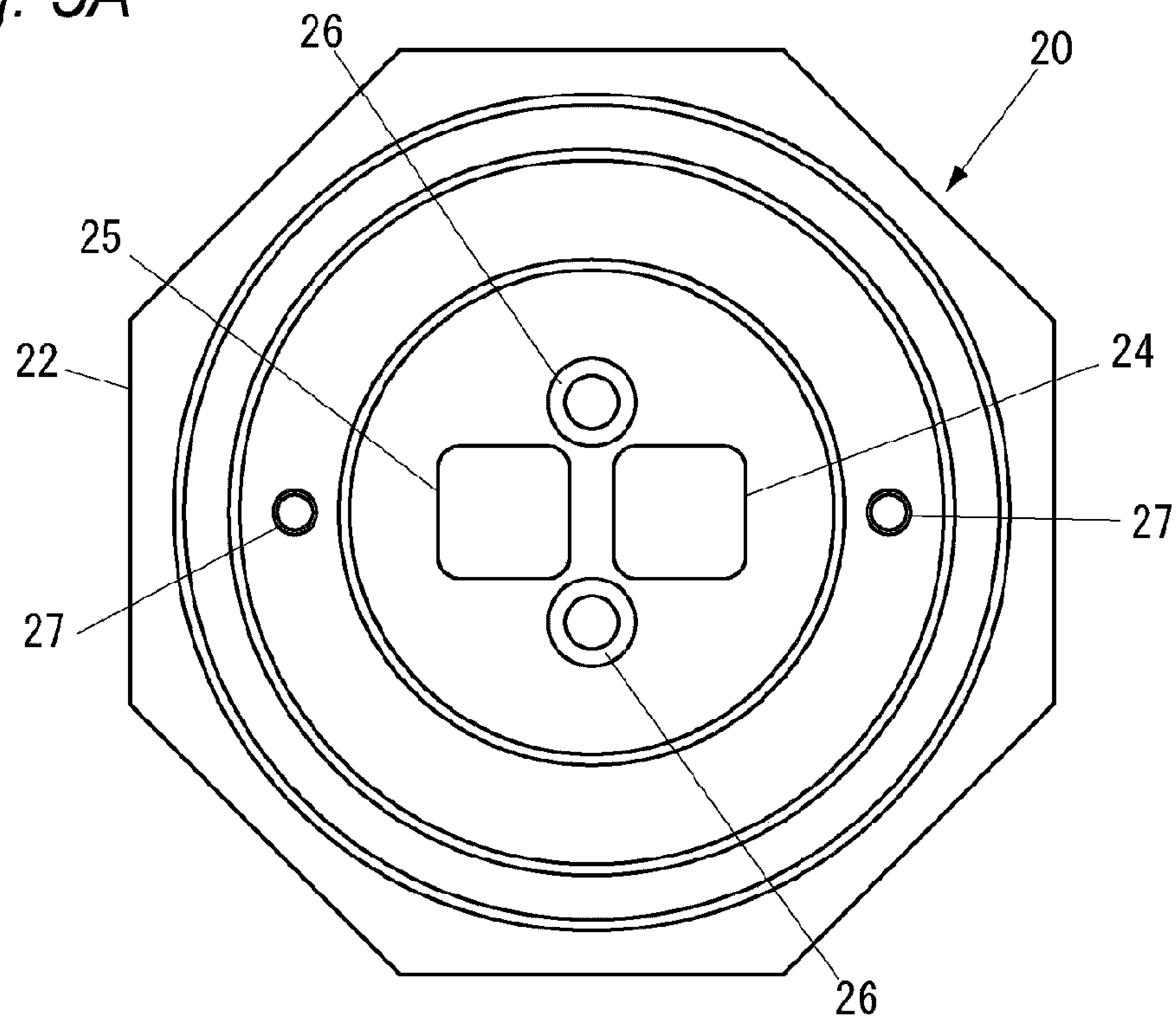

Fig. 5B

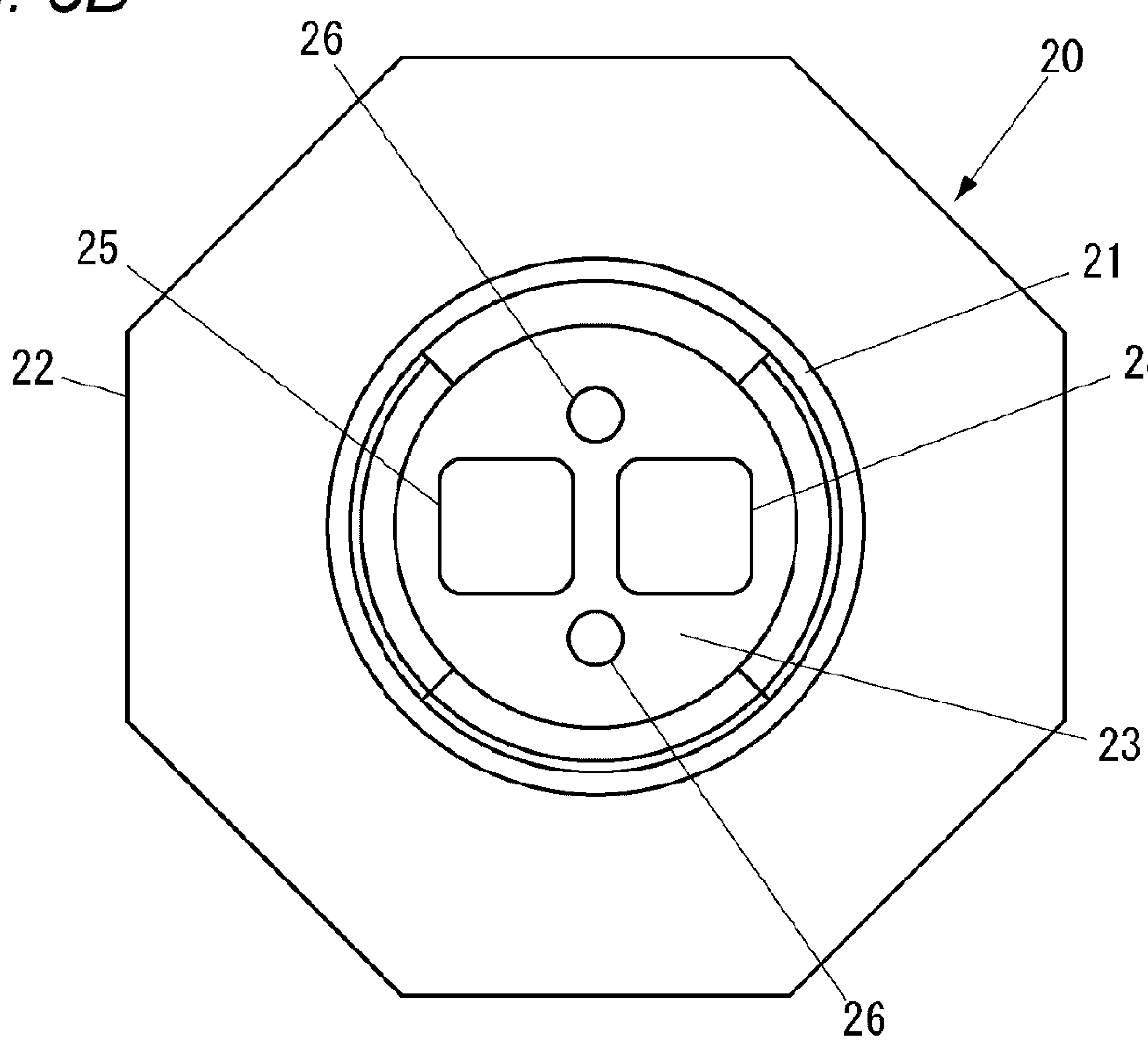

Fig. 6A

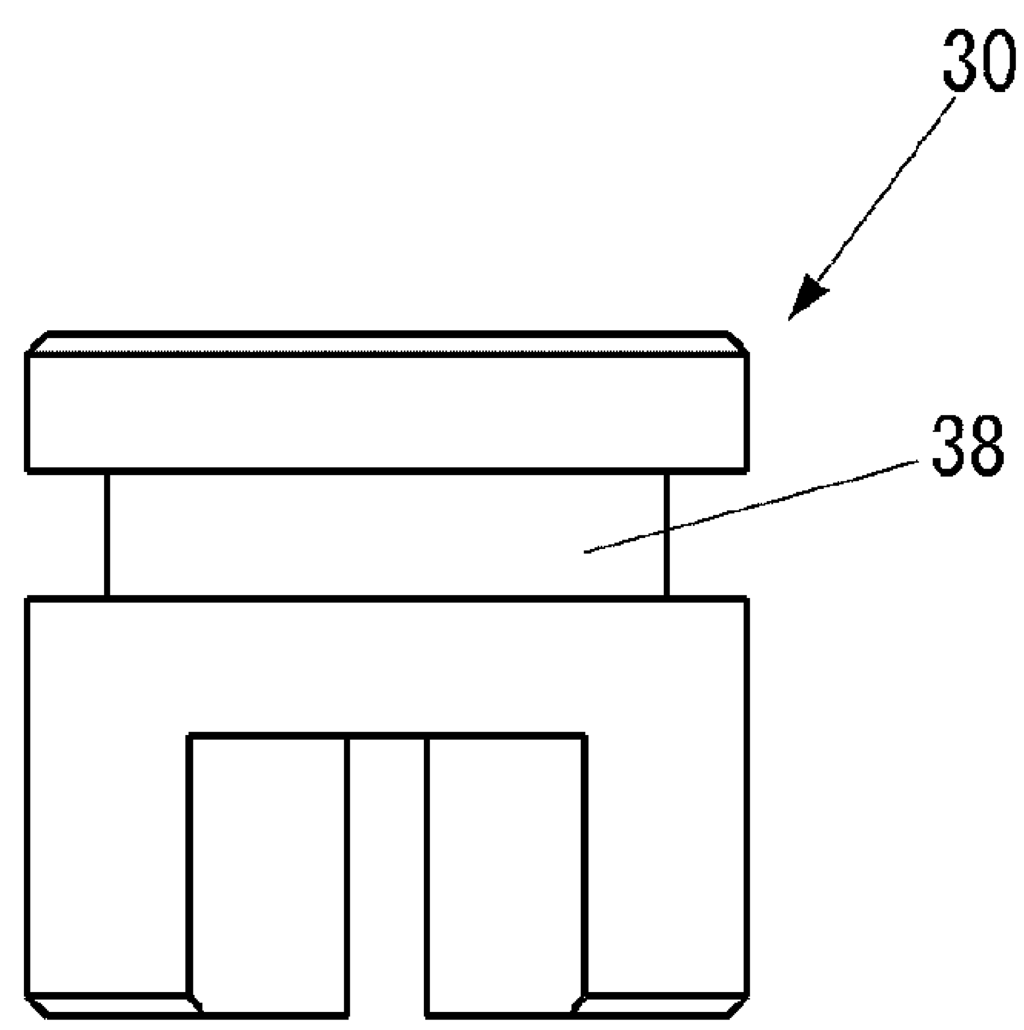

Fig. 6B

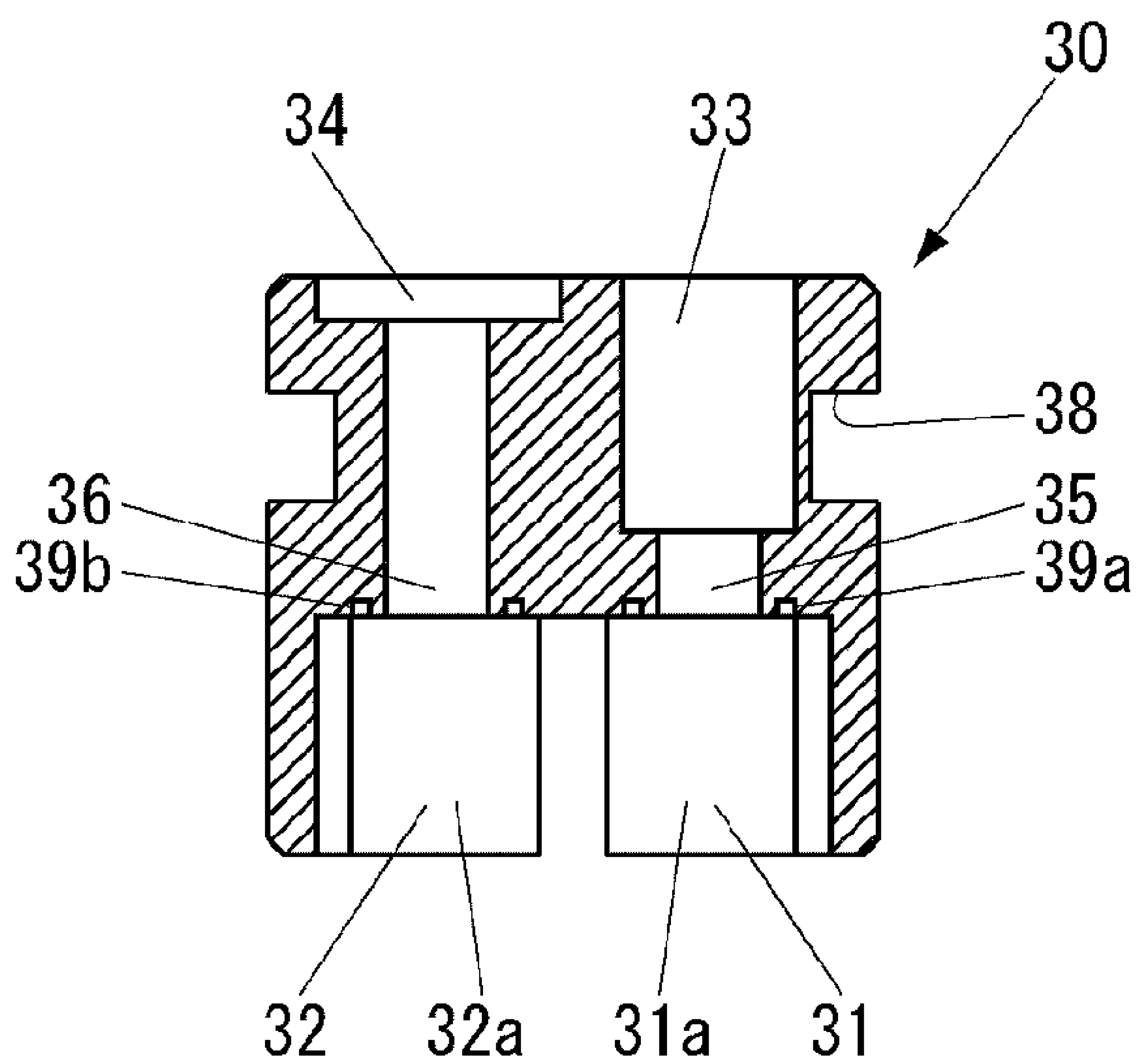

Fig. 7A

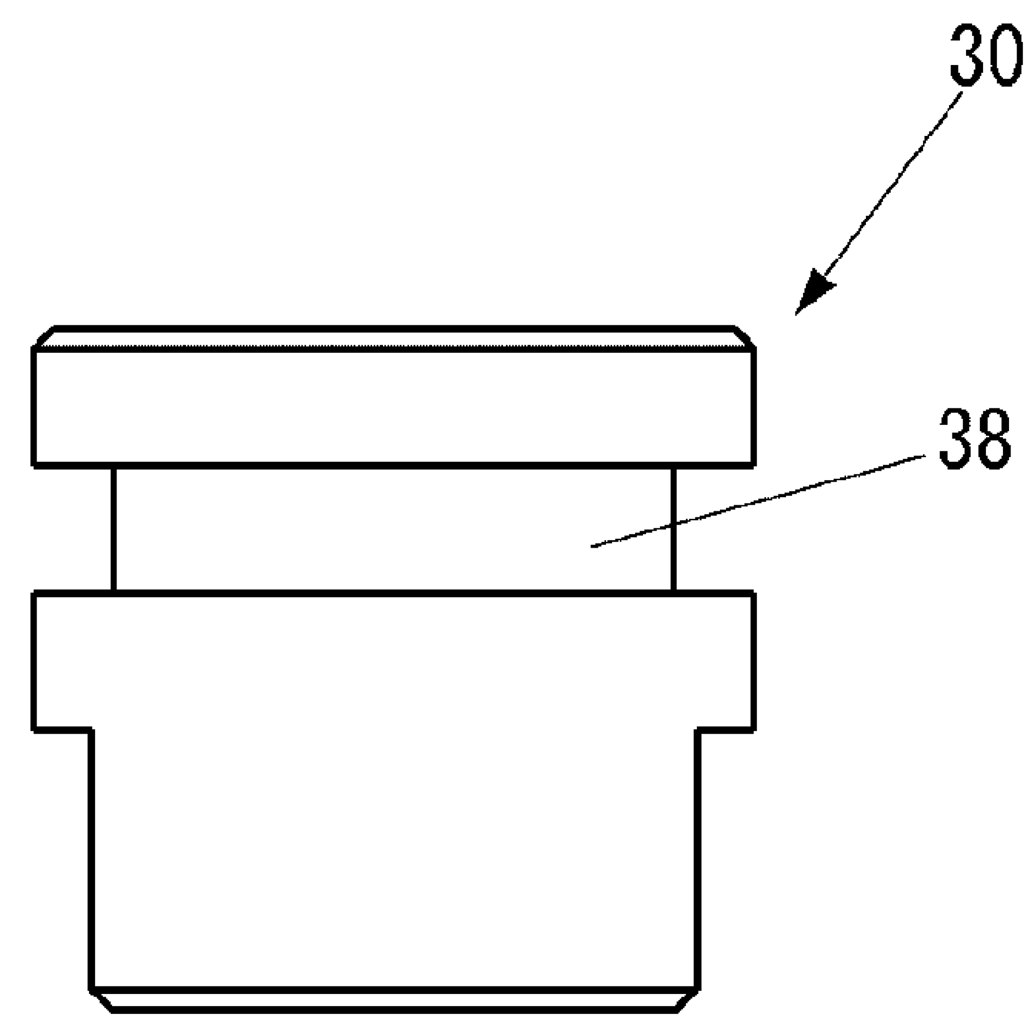

Fig. 7B

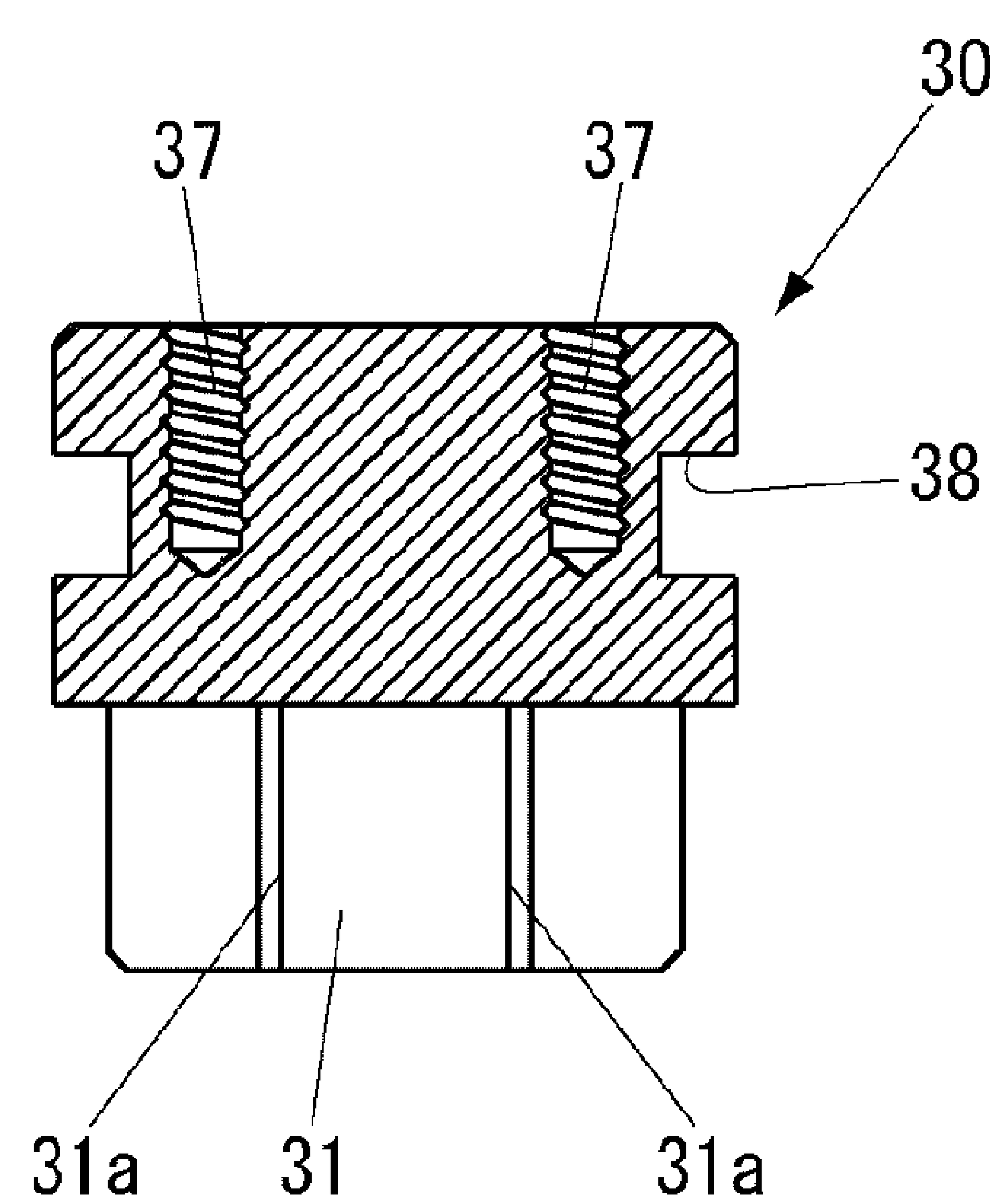

Fig. 8A

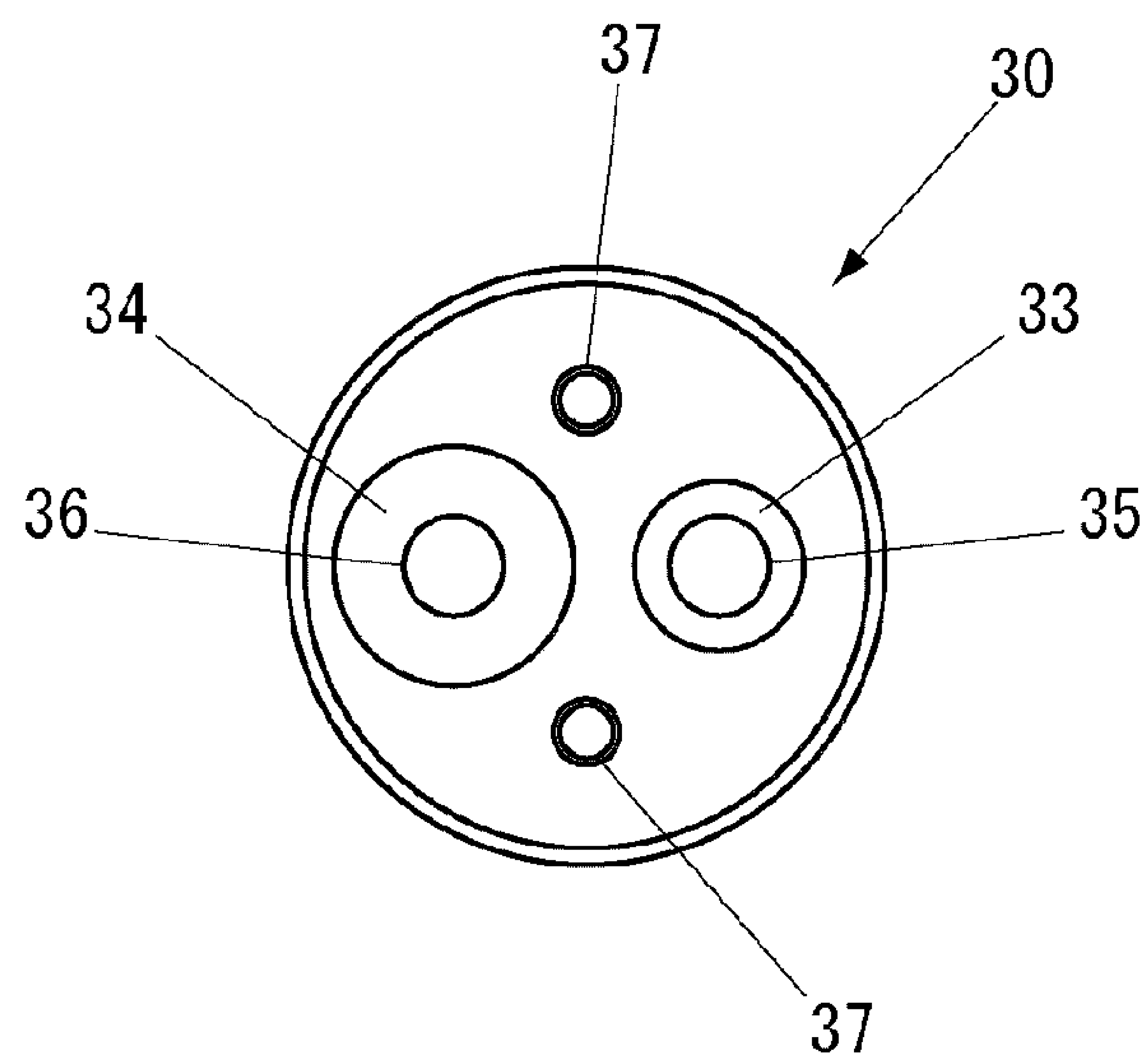

Fig. 8B

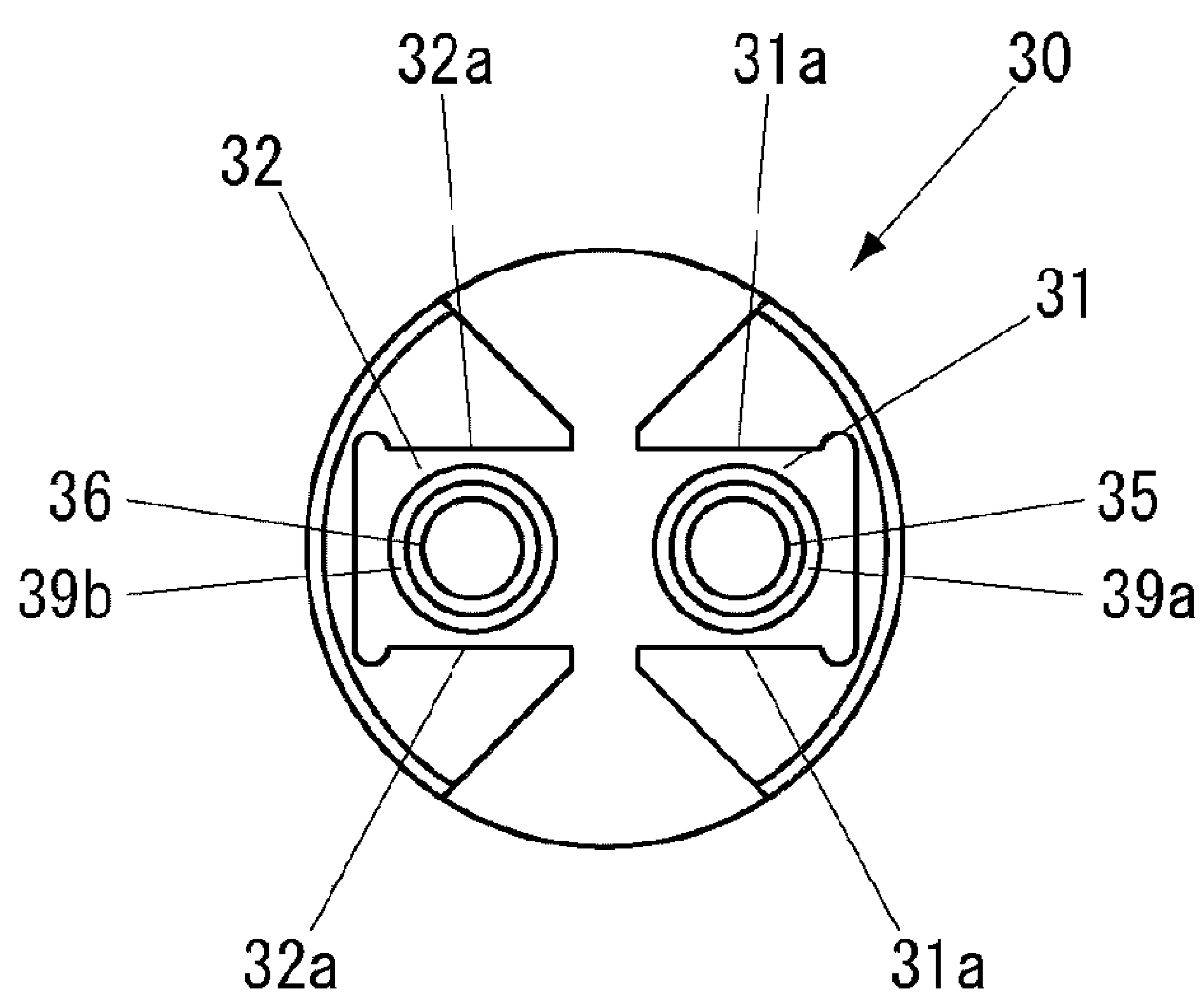

Fig. 9

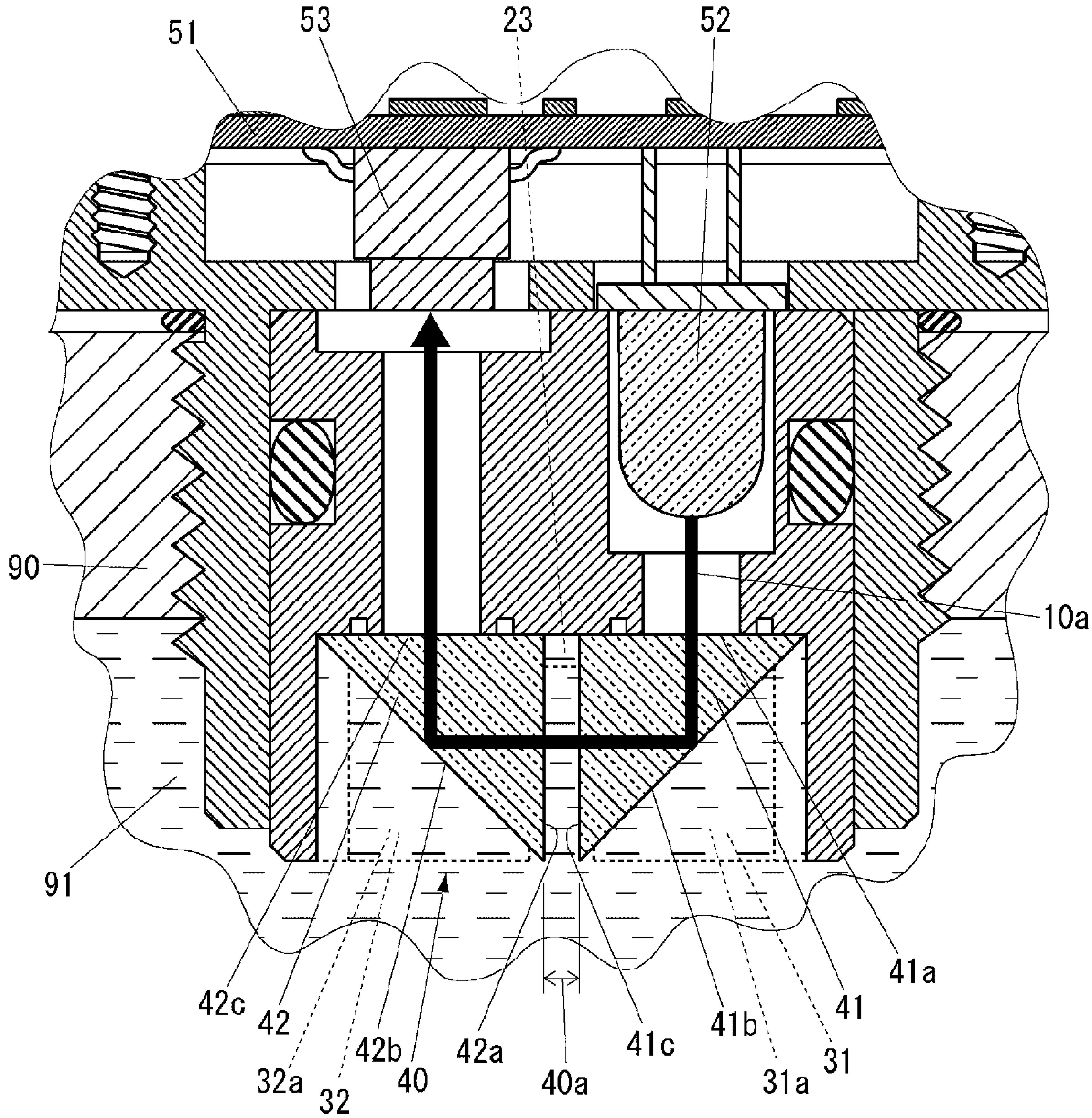
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Fig. 10A

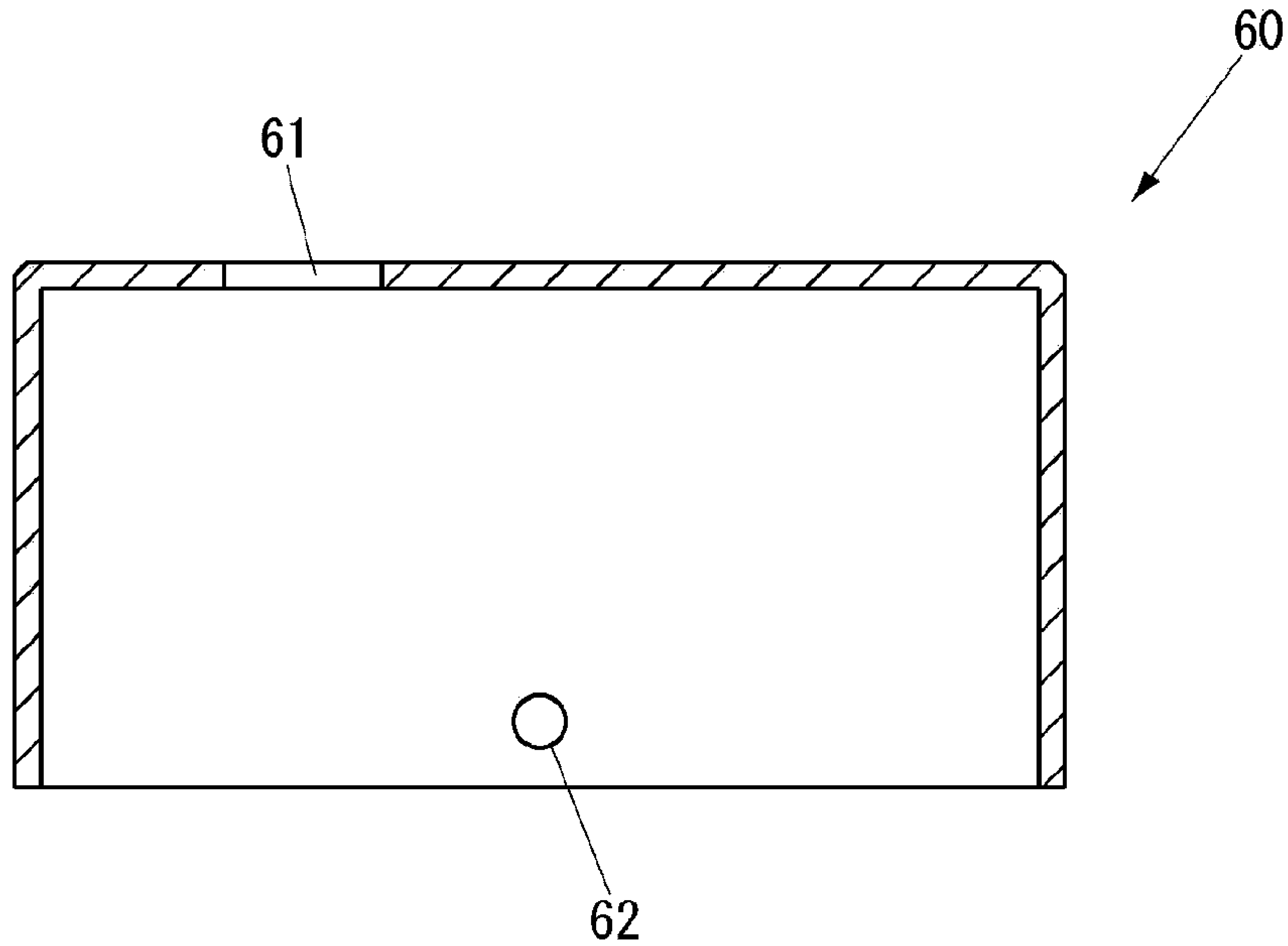


Fig. 10B

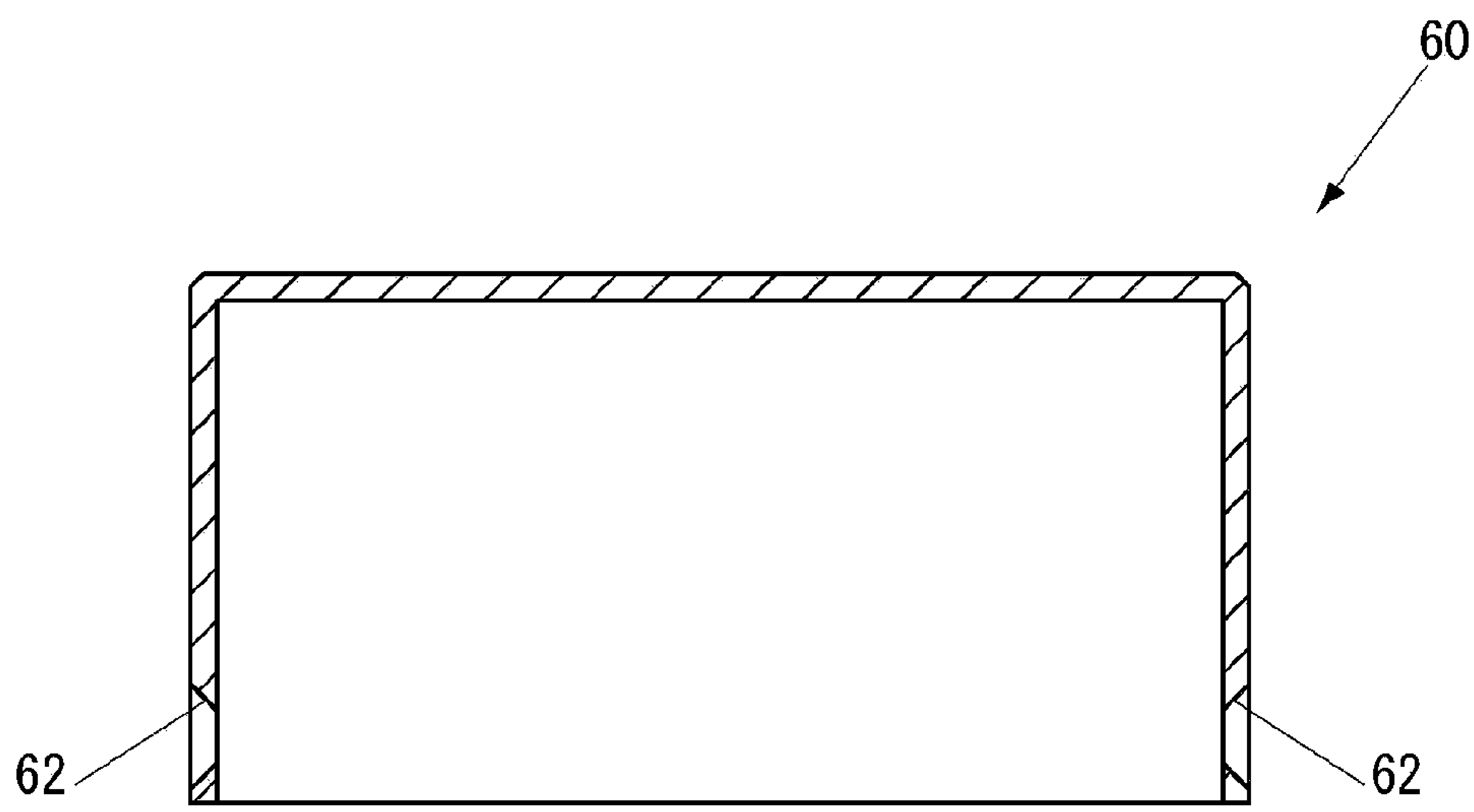


Fig. 11A

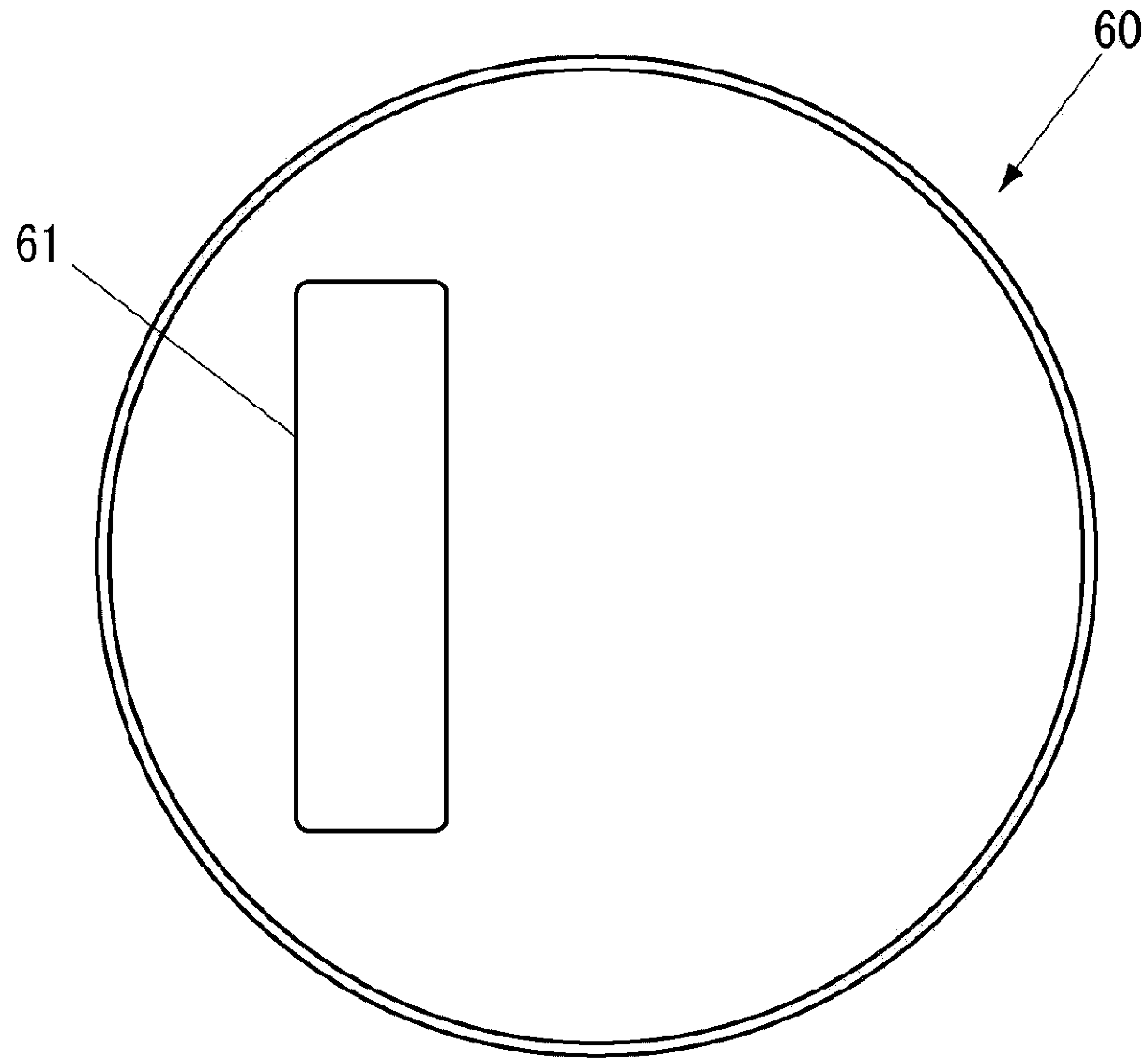
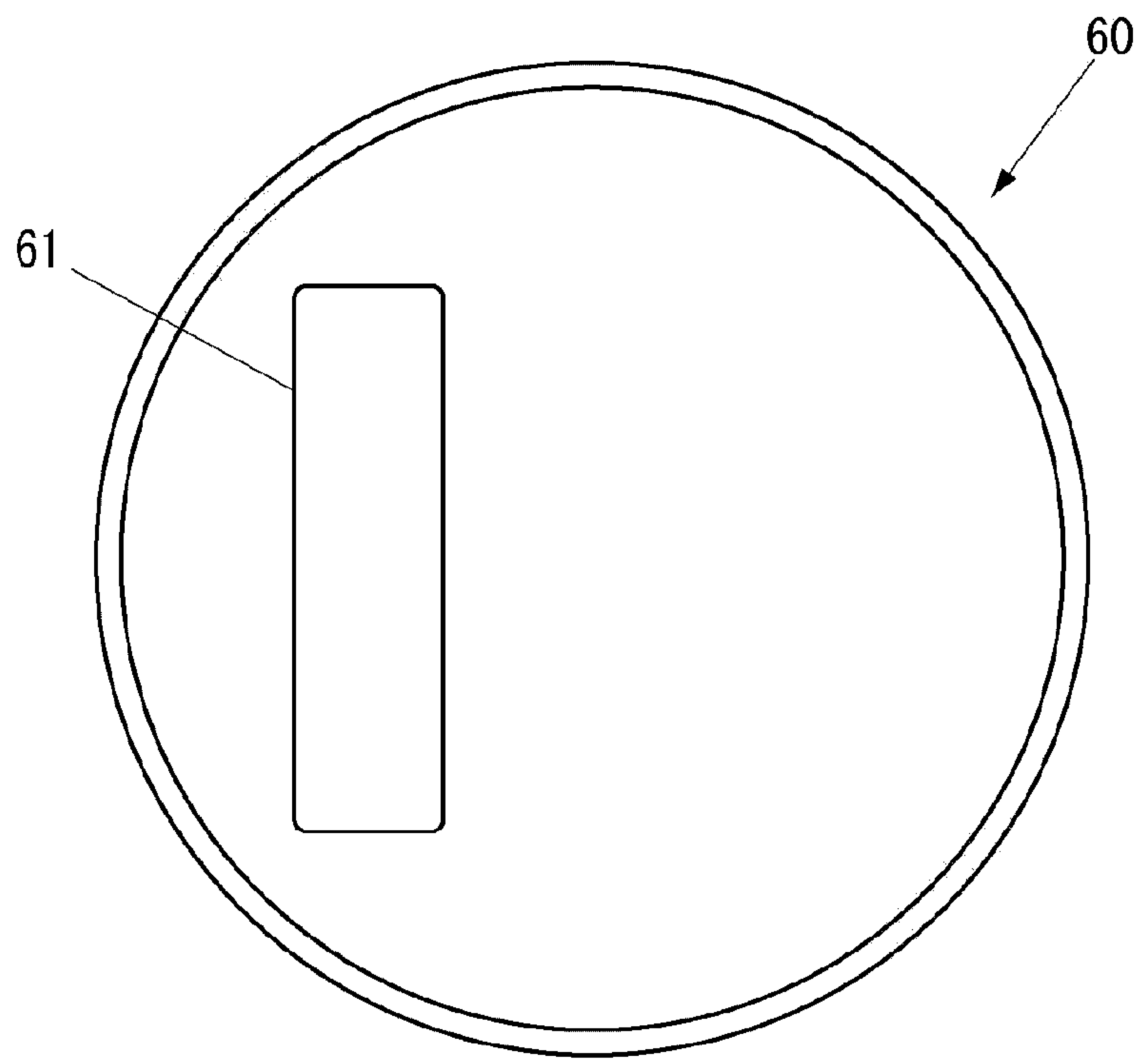


Fig. 11B



OPTICAL SENSOR FOR DETECTING LUBRICANT DETERIORATION

TECHNICAL FIELD

The invention relates to an optical sensor for detecting deterioration of a machine lubricant.

BACKGROUND ART

As a lubricant deterioration sensor, an oil deterioration sensor in which an oil intrusion clearance for intrusion of a lubricant is formed on an optical path from an infrared LED (Light Emitting Diode) to a photodiode has been known. The oil deterioration sensor detects an amount of light which exits from the infrared LED and is absorbed by the lubricant in the oil intrusion clearance based on an amount of light received by the photodiode, and determines a degree of deterioration of the lubricant that correlates to the detected amount of absorbed light (see; for instance, Patent Documents 1 and 2).

However, the oil deterioration sensor described in Patent Documents 1 and 2 can detect a concentration of insoluble substance in the lubricant as a degree of deterioration of the lubricant but has a problem that types of contaminants in the lubricant can not be specified.

As a technique for specifying a type of contaminant in a lubricant, a technique in which a light is irradiated to a membrane filter by an LED after filtration of a lubricant is known. In the technique, a light reflected from contaminants on the membrane filer is converted by a light receiving element into RGB digital values, and types of the contaminants in the lubricant are specified according to the converted RGB digital values (see; for instance, Non-Patent Documents 1 and 2).

CITATION LIST

Patent Documents

Patent Document 1: JP-A-7-146233

Patent Document 2: JP-A-10-104160

Non-Patent Document 1: Tomohiko YAMAGUCHI, four others, "Method for determining hues of contaminants in a lubricant," Engineering Department of Fukui University, Study Report March 2003, Vol. 51, No. 1, pp. 81 to 88.

Non-Patent Document 2: Tomonori HONDA, "Technique for diagnosing and inspecting deterioration of a lubricant," Academic Journal of Precision Engineering, 2009, Vo. 75, No. 3, pp. 359-362

SUMMARY OF INVENTION

Technical Problem

However, in the techniques described in Non-Patent Documents 1 and 2, it is needed to sample a lubricant from a machine and to filter the sample by a membrane filter. Accordingly, the techniques have a problem that an instancy is inferior.

Accordingly, an object of the present invention is to provide a lubricant deterioration sensor capable of instantly specifying types of contaminants in a lubricant of a machine.

Solution to Problem

An optical sensor, comprising:

a light emitting element for emanating light;

a light receiving element for detecting the light, disposed adjacent to the light emitting element;

a clearance forming member forming a fluid clearance in which a fluid enters;

a support member supporting the light emitting element, the light receiving element and the clearance forming member;

an optical path surrounding member, wherein

the clearance forming member is transmissive so that the light emitted from the light emitting element,

the fluid clearance is provided on an optical path from the light emitting element to the light receiving element, and

the optical path surrounding member surrounds at least a portion of the optical path.

By means of the configuration, the optical sensor of the invention detects colors from light of, among white light rays emitted from the white light emitting element, wavelengths that are not absorbed by contaminants in the fluid at the fluid clearance by use of the color light receiving element, so that colors of the contaminants in the fluid of the machine can be instantly detected. In other words, the optical sensor of the invention can instantly specify, on the basis of the colors detected by the color light receiving element, types of contaminants in the fluid of the machine. Further, the optical path surrounding member covers the optical path so as to suppress effects by disturbance, thus the detection accuracy can be improved.

In the lubricant deterioration sensor according to the present invention,

a space provided on the optical path between the light emitting element and the clearance forming member may be formed by a hole, and

a space provided on the optical path between the light receiving element and the clearance forming member may be formed by a hole.

By means of the configuration, the optical path can be prevented from occurring a diffused reflection, thus the detection accuracy can be improved.

In the lubricant deterioration sensor according to the present invention,

the light emitting element and the light receiving element may be accommodated in the optical path surrounding member at a position opposite to the clearance forming member. By means of the configuration, the light emitting element and the light receiving element can be protected from being affected from the thermal of the fluid, thus the detection accuracy can be improved.

In the lubricant deterioration sensor according to the present invention, the clearance forming member may have two rectangular prisms each of which has the reflection surface for bending the optical path, so that the optical path is bent by the reflection surfaces of the two rectangular prisms, and the oil clearance may be formed between the two rectangular prisms.

The configuration makes it possible to miniaturize the lubricant deterioration sensor of the invention by means of a simple configuration including a smaller number of parts.

The lubricant deterioration sensor according to the present invention may further include a screw portion configured to fix the optical sensor to a mating member, wherein the optical path surrounding member is disposed inside of the screw portion.

By means of the configuration, the configuration makes it possible to miniaturize the lubricant deterioration sensor of the invention by means of a simple configuration including a smaller number of parts

In the lubricant deterioration sensor according to the present invention,

a width of a space on the optical path between the light emitting element and the clearance forming member at a side of the clearance forming member may be shorter than a width of the space at a side of the light emitting element, and

the optical path between the light emitting element and the clearance forming member and the optical path between the light receiving element and the clearance forming member may extend in a direction in which the optical sensor is inserted to a mating member.

By means of the configuration, the activity for assembling can be improved.

In the lubricant deterioration sensor according to the present invention, a groove surrounding an opening of a space on the optical path between the light emitting element and the clearance forming member may be formed on a surface of the supporting member to which the clearance forming member is attached. By means of the configuration, the adhesive for attaching the clearance forming member can be prevented from irrupting into the space on the optical path.

An optical sensor, comprising:

a light emitting element that emits a light;

a light receiving element that detects the light;

a transmissive part that includes an incident surface to which the light is incident from the light emitting element and an exit surface from which the light incident on the incident surface, and defines a gap, into which a lubricant enters, in an optical path from the incident surface to the exit surface; and

a first narrowing part that narrows the optical path from the light emitting element to the incident surface.

The first narrowing part may include a first part defining a first hole in which the light emitting element is accommodated; and a second part defining a second hole which communicates the first hole with the incident surface and has a first narrowed portion, and an area of the optical path in the first narrowed portion may be smaller than an area of the optical path in the first hole.

The optical sensor may further comprise a second narrowing part that narrows the optical path from the exit surface to the light receiving element.

The second narrowing part may include a third part defining a third hole in which the light receiving element is accommodated; and a fourth part defining a fourth hole which communicates the third hole with the exit surface and has a second narrowed portion. An area of the optical path in the second narrowed portion may be smaller than an area of the optical path in the third hole.

The optical sensor may be configured such that:

the transmissive part includes a first rectangular prism and a second rectangular prism,

the first rectangular prism has:

a first incident surface which is the incident suface;

a first exit surface orthogonal to the first incident surface;

a first reflection surface which is an inclined surface with respect to an apex angle being right angle and which bends the optical path of the light incident on the first incident surface;

a pair of first side surfaces which sandwitch the first incident surface, the first exit surface and the first reflection surface,

the second rectangular prism has:

a second incident surface which opposes the first exit surface;

a second exit surface which is orthogonal to the second incident surface and which is the exit surface;

a second reflection surface which is an inclined surface with respect to an apex angle being right angle and which bends the optical path of the light incident on the second incident surface;

a pair of first side surfaces which sandwitch the first incident surface, the first exit surface and the first reflection surface,

at least one of the first rectangular prism and the second rectangular prism is an object to be fixed,

the optical sensor includes a wall to which a surface including the side surfaces is fixed, in the object to be fixed.

The optical sensor may further comprise a supporting member which supports the light emitting element, the light receiving element and the transmissive part. The supporting member may include the first narrowing part.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a front view of a lubricant deterioration sensor of one embodiment of the invention.

FIG. **2** is a front cross sectional view of the lubricant deterioration sensor shown in FIG. **1**.

FIG. **3**A it is a front view of a support member shown in FIG. **1**, and FIG. **3**B is a front cross sectional view of the support member shown in FIG. **1**.

FIG. **4**A it is a side view of the support member shown in FIG. **1**, and FIG. **4**B is a side cross sectional view of the support member shown in FIG. **1**.

FIG. **5**A is a plan view of the support member shown in FIG. **1**, and FIG. **5**B is a bottom view of the support member shown in FIG. **1**.

FIG. **6**A is a front view of a holder shown in FIG. **1**, and FIG. **6**B is a front cross sectional view of the holder shown in FIG. **1**.

FIG. **7**A is a side view of the holder shown in FIG. **1**, and FIG. **7**B is a side cross sectional view of the holder shown in FIG. **1**.

FIG. **8**A is a plan view of the holder shown in FIG. **1**, and FIG. **8**B is a bottom view of the holder shown in FIG. **1**.

FIG. **9** is a view showing an optical path from a white LED to an RGB sensor shown in FIG. **2**.

FIG. **10**A is a front cross sectional view of a cover shown in FIG. **1**, and FIG. **10**B is a side cross sectional view of the cover shown in FIG. **1**.

FIG. **11**A is a plan view of the cover shown in FIG. **1**, and FIG. **11**B is a bottom view of the cover shown in FIG. **1**.

DESCRIPTION OF EMBODIMENTS

An embodiment of the invention is hereunder described by reference to the drawings.

First, a configuration of a lubricant deterioration sensor of the embodiment is described.

FIG. **1** is a front view of an optical sensor **10** of the embodiment. FIG. **2** is a front cross sectional view of the lubricant deterioration sensor **10** mounted in a machine **90**. In this embodiment, the optical sensor is used as a lubricant deterioration sensor **10**.

As shown in FIGS. **1** and **2**, the lubricant deterioration sensor **10** is an apparatus for detecting deterioration of a lubricant **91** of the machine **90** mounted in the machine **90**. Although in the present embodiment this sensor **10** is used for the oil or the lubricant as an example, the sensor **10** can be used for any other fluid.

The lubricant deterioration sensor **10** includes a support member **20** that is made of an aluminum alloy for supporting respective parts of the lubricant deterioration sensor **10**, a holder **30** that is secured to the support member **20** with a screw **11** and that is made of an aluminum alloy; a clearance forming member **40** that is retained by the holder **30**, an electronic parts group **50** outfitted with a circuit board **51** that is secured to the support member **20** with screws **12**, and a cover **60** that is secured to the support member **20** with a screw **13** and that is made of an aluminum alloy.

The clearance forming member **40** is made up of two rectangular glass prisms **41** and **42**, and an oil clearance **40**a that is a clearance for intrusion of the lubricant **91** is formed between the two rectangular prisms **41** and **42**.

The electronic parts group **50** includes a white LED **52** mounted on the circuit board **51**, an RGB sensor **53** mounted on the circuit board **51**, a circuit board **54** placed opposite the white LED **52** and the RGB sensor **53** with reference to the circuit board **51**, a plurality of columns **55** for anchoring the circuit board **51** and the circuit board **54**, a circuit board **56** placed opposite the circuit board **51** with reference to the circuit board **54**, a plurality of columns **57** for securing the circuit board **54** and the circuit board **56**; and a connector **58** mounted opposite the circuit board **54** with reference to the circuit board **56**. A plurality of electronic parts are mounted on the circuit board **51**, the circuit board **54**, and the circuit board **56**. Further, the circuit board **51**, the circuit board **54**, and the circuit board **56** are electrically connected to each other.

The lubricant deterioration sensor **10** is equipped with an O ring **14** for preventing leakage of the lubricant **91** from a clearance between the support member **20** and the machine **90** and an O ring **15** for preventing leakage of the lubricant **91** from a clearance between the support member **20** and the holder **30**.

FIG. **3**A is a front view of the support member **20**. FIG. **3**B is a front cross sectional view of the support member **20**. FIG. **4**A is a side view of the support member **20**. FIG. **4**B is a side cross sectional view of the support member **20**. FIG. **5**A is a plan view of the support member **20**. FIG. **5**B is a bottom view of the support member **20**.

As shown in FIGS. **1** to **5**B, the support member **20** includes a screw section **21** secured to a tapped hole **90***a* of the machine **90**, a hexagonal tool contact **22** that is to be gripped with a tool when the screw section **21** is rotated with respect to the tapped hole **90***a* of the machine **90**, and a holder housing section **23** for housing the holder **30**. Moreover, the support member **20** are formed with a hole **24** for insertion of the white LED **52**, a hole **25** for insertion of the RGB sensor **53**, two holes **26** for insertion of the screw **11**, two tapped holes **27** for insertion of the screws **12**, and two tapped holes **28** for insertion of the screw **13**.

The support member **20** supports the white LED **52** and the RGB sensor **53** by way of the circuit board **51**. The support member **20** supports the clearance forming member **40** by way of the holder **30**.

FIG. **6**A is a front view of the holder **30**. FIG. **6**B is a front cross sectional view of the holder **30**. FIG. **7**A is a side view of the holder **30**. FIG. **7**B is a side cross sectional view of the holder **30**. FIG. **8**A is a plan view of the holder **30**. FIG. **8**B is a bottom view of the holder **30**. FIG. **9** is a view showing an optical path **10***a* from the white LED **52** to the RGB sensor **53**.

As shown in FIGS. **1** and **2** and FIGS. **6**A to **9**, the holder **30** includes a prism housing **31** that houses the rectangular prism **41**, a prism housing **32** that houses the rectangular prism **42**, and an LED housing **33** that houses the white LED **52**. The holder **30** are formed with a hole **34** for the RGB sensor **53**, a hole **35** that establishes mutual communication between the prism housing **31** and the LED housing **33**, a hole **36** that establishes mutual communication between the prism housing **32** and the hole **34**, two tapped holes **37** for screw-engagement of the screw **11**, a groove **38** to which the O ring **15** fits, an annular groove **39***a* for preventing an adhesive which fixes the rectangular prism **41** to the prism housing **31** from entering the hole **35**, and an annular groove **39***b* for preventing an adhesive which fixes the rectangular prism **42** to the prism housing **32** from entering the hole **36**. The grooves **39***a*, **39***b* for preventing the adhesive from entering the holes **35**, **36** may be provided on the support member **20**.

The prism housing **31** includes two walls **31***a* between which the rectangular prism **41** is to be inserted. The walls **31***a* fix the rectangular prism **41** by means of an adhesive. The prism housing **32** includes two walls **32***a* between which the rectangular prism **42** is to be inserted. The walls **32***a* fix the rectangular prism **42** by means of an adhesive.

The holder **30** surrounds at least a portion of the optical path **10***a* from the white LED **52** to the RGB sensor **53** by means of the LED housing **33**, the hole **35**, the prism housing **31**, the prism housing **32**, the hole **36**, the hole **34**, making up an optical path surrounding member of the invention. The grooves **39***a*, **39***b* for preventing the adhesive from entering the holes **35**, **36** may be provided on the optical path surrounding member.

A surface of the holder **30** is treated by antireflection; for instance, mat black anodized aluminum treatment.

As shown in FIG. **9**, the oil clearance **40***a* of the clearance forming member **40** is placed on the optical path **10***a* from the white LED **52** to the RGB sensor **53**.

The rectangular prisms **41** and **42** are transmissive so that light emitted from the white LED **52** transmits therethrough. The rectangular prism **41** has an incident surface **41***a* on which light emitted by the white LED **52** falls, a reflection surface **41***b* that reflects the light fell on the incident surface **41***a*, to thus make a 90-degree turn of a traveling direction of light, and an exit surface **41***c* from which the light reflected by the reflection surface **41***b* exits. The rectangular prism **42** has an incident surface **42***a* on which light exited from the exit surface **41***c* of the rectangular prism **41** falls, a reflection surface **42***b* that reflects the light fell on the incident surface **42***a*, to thus make a 90-degree turn of a traveling direction of light, and an exit surface **42***c* from which the light reflected by the reflection surface **42***b* exits.

The incident surface **41***a*, the reflection surface **41***b*, and the exit surface **41***c* of the rectangular prism **41**, and the incident surface **42***a*, the reflection surface **42***b*, and the exit surface **42***c* of the rectangular prism **42** are optically polished. The reflection surface **41***b* of the rectangular prism **41** and the reflection surface **42***b* of the rectangular prism **42** each are covered with an aluminum evaporated film. In order to protect the aluminum evaporated film that has a low degree of hardness and adhesion, the aluminum evaporated film is further coated with an SiO_2 film.

The optical path **10***a* is bent at 90-degree angle on the reflection surface **41***b* of the rectangular prism **41**, further is bent at 90-degree angle also on the reflection surface **42***b* of the rectangular prism **42**. To be specific, the optical path **10***a* is bent at 180 degrees angle by the clearance forming member **40**.

A distance between the exit surface **41***c* of the rectangular prism **41** and the incident surface **42***a* of the rectangular prism **42** is a length of the oil clearance **40***a*. The length of the oil clearance **40***a* is 1 millimeter for instance. When the length of the oil clearance **40***a* is too short, contaminants in the lubricant **91** become difficult to flow through the oil clearance **40***a* appropriately, so that a degree of detection accuracy of a color of the contaminants in the lubricant **91** deteriorates. In the meantime, when the length of the oil clearance **40***a* is too long, light emitted from the white LED **52** is too absorbed by the contaminants in the lubricant **91** in the oil clearance **40***a* to reach the RGB sensor **53**, so that the degree of detection accuracy of the color of the contaminants in the lubricant **91** also deteriorates. Consequently, it is preferable that the length of the oil clearance **40***a* be appropriately set such that the degree of detection accuracy of the color of the contaminants in the lubricant **91** improves.

The white LED **52** is an electronic part that emits white light and makes up a light emitting element of the invention. For instance, NSPW500GS-K1 manufactured by Nichia Corporation, can be used as the white LED **52**. Although in the present embodiment the white LED **52** is used as the light emitting element, the light emitting element can be any other light emitting device. The light emitted by the light emitting element is preferably visible light, but may be light having wavelength other than the visible light.

The RGB sensor **53** is an electronic part that detects a color of received light and makes up a color light receiving element of the invention. For instance, S9032-02 manufactured by Hamamatsu Photonics K.K. can be used as the RGB sensor **53**.

As shown in FIG. **2**, the connector **58** is connected to a connector **59** of an external device of the lubricant deterioration sensor **139***a* and is fed with electric power from the external device by way of a connector **95**. A detection result of the lubricant deterioration sensor **10** is output to the external device as an electric signal by way of the connector **95**.

FIG. **10**A is a front cross sectional view of the cover **60**. FIG. **10**B is a side cross sectional view of the cover **60**. FIG. **11**A is a plan view of the cover **60**. FIG. **11**B is a bottom view of the cover **60**.

As shown in FIGS. **1**, **2**, **10**A to **11**B, the cover **60** has a hole **61** for insertion of the connector **58** and two holes **62** for insertion of the screw **13**.

A surface of the cover **60** is treated by antireflection; for instance, mat black anodized aluminum treatment.

The optical sensor **10** includes a first narrowing part that narrows the optical path **10***a* from the light emitting element **52** to the incident surface **41***a*.

The first narrowing part includes a first part defining a first hole in which the light emitting element **52** is accommodated, a second part defining a second hole which communicates the first hole with the incident surface **41***a* and has a first narrowed portion. An area of the optical path **10***a* in the first narrowed portion is smaller than an area of the optical path **10***a* in the first hole.

The optical sensor **10** includes a second narrowing part that narrows the optical path **10***a* from the exit surface **42***c* to the light receiving element **53**.

The second narrowing part includes a third part defining a third hole in which the light receiving element **53** is accommodated, and a fourth part defining a fourth hole which communicates the third hole with the exit surface **42***c* and has a second narrowed portion. An area of the optical path **10***a* in the second narrowed portion is smaller than an area of the optical path **10***a* in the third hole.

The first rectangular prism **41** has a first incident surface which is the incident surface **41***a*, a first exit surface **41***c* orthogonal to the first incident surface **41***a*, a first reflection surface **41***b* which is an inclined surface with respect to an apex angle being right angle and which bends the optical path **10***a* of the light incident on the first incident surface **41***a*, a pair of first side surfaces which sandwich the first incident surface **41***a*, the first exit surface **41***c* and the first reflection surface **41***b*.

The second rectangular prism **42** has a second incident surface **42***a* which opposes the first exit surface **41***c*, a second exit surface **42***c* which is orthogonal to the second incident surface **42***a* and which is the exit surface **42***c*, a second reflection surface **42***b* which is an inclined surface with respect to an apex angle being right angle and which bends the optical path **10***a* of the light incident on the second incident surface **42***a*, a pair of second side surfaces which sandwich the second incident surface **42***a*, the second exit surface **42***c* and the second reflection surface **42***b*.

At least one of the first rectangular prism **41** and the second rectangular prism **42** is an object to be fixed. The optical sensor **10** includes a wall to which a surface including the side surfaces is fixed, in the object to be fixed.

The support member **20** which supports the light emitting element **52**, the light receiving element **53** and the transmissive part **41**, **42**. The support member **20** includes the first narrowing part.

Next, a method for assembling the lubricant deterioration sensor **10** is described.

First, an adhesive is applied to two surfaces of the surfaces of the rectangular prism **41** that contact the two walls **31***a* of the prism housing **31** as well as to an outer peripheral surface of the groove **39***a* that contacts the incident surface **41***a* of the rectangular prism **41** of the prism housing **31** of the holder **30**, whereby the rectangular prism **41** is secured to the prism housing **31** by means of the adhesive. In addition, an adhesive is applied to two surfaces of the surfaces of the rectangular prism **42** that contact the two walls **32***a* of the prism housing **32** as well as to an outer peripheral surface of the groove **39***b* which contacts the exit surface **42***c* of the rectangular prism **42** of the prism housing **32** of the holder **30**, whereby the rectangular prism **42** is secured to the prism housing **32** by means of the adhesive. Further, the white LED **52** is secured to the LED housing **33** of the holder **30** by means of the adhesive.

Next, the holder **30** outfitted with the O ring **15** is secured, by means of the screw **11**, to the holder housing **23** of the support member **20** outfitted with the O ring **14**.

The electronic parts group **50** into which various electronic parts except the white LED **52**; namely, the circuit board **51**, the RGB sensor **53**, and the connector **58**, are previously assembled is secured to the support member **20** by the screws **12**, thereby the white LED **52** is soldered to the circuit board **51**.

Finally, the cover **60** is secured to the support member **20** by the screw **13**.

A method for mounting the lubricant deterioration sensor **10** to the machine **90** is now described.

First, the tool contact **22** of the support member **20** is pinched with a tool, and the screw **21** of the support member **20** is screwed into the tapped hole **90***a* of the machine **90**, whereby the lubricant deterioration sensor **10** is secured to the machine **90**.

The connector **95** of an external device of the lubricant deterioration sensor **10** is connected to the connector **58**.

Next, operation of the lubricant deterioration sensor **10** is described.

In the lubricant deterioration sensor **10**, white light is emitted from the white LED **52** by means of the electric power fed from an external device by way of the connector **58**.

The lubricant deterioration sensor **10** outputs amounts of RGB colors of light received by the RGB sensor **53** as an electric signal to an external device by way of the connector **58**.

The lubricant deterioration sensor **10** can also be separately equipped with a sensor other than the RGB sensor **53**. For instance, when a temperature sensor for detecting a temperature of the lubricant **91** is included in the electronic parts group **50**, the lubricant deterioration sensor **10** can output a temperature detected by the temperature sensor to an external device as an electric signal by way of the connector **58**.

As described above, the lubricant deterioration sensor **10** detects colors from light of, among white light rays emitted from the white LED **52**, wavelengths that are not absorbed by contaminants in the lubricant **91** in the oil clearance **40***a* by use of the RGB sensor **53**, so that colors of the contaminants in the lubricant **91** of the machine **91** can be instantly detected. In other words, the lubricant deterioration sensor can instantly specify, on the basis of the colors detected by the RGB sensor **53**, types and amounts of contaminants in the lubricant **91** of the machine **90** by use of an external device, like a computer. Incidentally, the lubricant deterioration sensor **10**, electronic parts that specify types and amounts of contaminants in the lubricant **91** of the machine **90** from the colors detected by the RGB sensor **53** can also be included in the electronic parts group **50**.

In the lubricant deterioration sensor **10**, the reflection surfaces **41***b* and **42***b* for refracting the optical path **10***a* are formed on the clearance forming member **40**. Therefore, when compared with the configuration in which the optical path **10***a* from the white LED **52** to the RGB sensor **53** is straightforward, the entirety of the sensor can be miniaturized by placing the white LED **52** and the RGB sensor **53** in close proximity to each other. Further, in the lubricant deterioration sensor **10**, the clearance forming member **40** plays the role of bending the optical path **10***a* as well as the role of forming the oil clearance **40***a*. Hence, when compared with a configuration separately provided with a member for refracting the optical path **10***a* instead of the clearance forming member **40**, the number of parts can be curtailed.

In particular, in the lubricant deterioration sensor **10**, the clearance forming member **40** is made up of the two rectangular prisms **41** and **42** on which there are formed the reflection surfaces **41***b* and **42***b* for effecting 90-degree refraction of the optical path **10***a*. The optical path **10***a* is subjected to 180-degree refraction by means of the reflection surfaces **41***b* and **42***b* of the two rectangular prisms **41** and **42**, and the oil clearance **40***a* is formed between the two rectangular prisms **41** and **42**. Hence, the lubricant deterioration sensor can be miniaturized by means of a simple configuration that includes a smaller number of parts.

Further, the lubricant deterioration sensor **10** is equipped with the holder **30** that surrounds at least a portion of the optical path **10***a*. The surface of the holder **30** is treated with antireflection processing. Hence, the RGB sensor **53** can be prevented from experiencing unwanted reflected light. Consequently, when compared with the configuration in which the RGB sensor **53** experiences unwanted reflected light, the lubricant deterioration sensor **10** can enhance the detection accuracy of colors of contaminants in the lubricant **91**.

In the lubricant deterioration sensor **10**, the surfaces of the clearance forming member **40** that form the oil clearance **40***a*; namely, the exit surface **41***c* of the rectangular prism **41** and the incident surface **42***a* of the rectangular prism **42**, can also be treated with oil repellent treatment. In the lubricant deterioration sensor **10**, when the exit surface **41***c* of the rectangular prism **41** and the incident surface **42***a* of the rectangular prism **42** are given oil repellent treatment, the exit surface **41***c* of the rectangular prism **31** and the incident surface **42***a* of the rectangular prism **42** are less susceptible to stains. Therefore a decrease in detection accuracy of colors of contaminants in the lubricant **91**, which would otherwise be caused by stains, can be prevented.

In the lubricant deterioration sensor **10**, the layout of the white LED **52** and the RGB sensor **53** may also be different from that described in the embodiment. For instance, in the lubricant deterioration sensor **10**, the optical path **10***a* from the white LED **52** to the RGB sensor **53** may also be straightforward.

In the lubricant deterioration sensor **10**, the optical path **10***a* can also be bended by means of a configuration other than the rectangular prism.

For instance, fluorine coating, a transparent silicone resin, and the like, are available as coating that makes it difficult for stains (sludge) in a lubricant to adhere.

The patent application is based on Japanese Patent Application JP-2010-269097 (filed on Dec. 2, 2010), the subject matter of which is incorporated herein by reference in its entirety.

INDUSTRIAL APPLICABILITY

The lubricant deterioration sensor of the invention enables instant specification of types of contaminants in a lubricant of a machine

REFERENCE SIGNS LIST

10 Lubricant Deterioration Sensor
10*a* Optical Path
20 Support Member
30 Holder (Optical Path Surrounding Member)
40 Clearance Forming Member
40*a* Oil Clearance
41 Rectangular Prism
41*b* Reflection Surface
41*c* Exit Surface (Surface that makes up Oil Clearance)
42 Rectangular Prism
42*a* Entrance Surface (Surface that makes up Clearance)
42*b* Reflection Surface
52 White Led (Light Emitting Element)
53 RGB Sensor (Color Receiving Element)
90 Machine
91 Lubricant

The invention claimed is:

1. An optical sensor, comprising:

a light emitting element for emanating light;

a light receiving element for detecting the light, disposed adjacent to the light emitting element;

a clearance forming member including a first reflection surface, a second reflection surface, and a fluid clearance in which a fluid enters;

a support member supporting the light emitting element, the light receiving element and the clearance forming member;

an optical path surrounding member, wherein the clearance forming member is transmissive so that the light emitted from the light emitting element transmits therethrough,

the fluid clearance is provided on an optical path from the light emitting element to the light receiving element such that light reflected from the first reflection surface passes through the fluid clearance before reaching the second reflection surface, and

the optical path surrounding member surrounds at least a portion of the optical path.

2. The optical sensor according to claim **1**, wherein

a space provided on the optical path between the light emitting element and the clearance forming member is formed by a hole, and

a space provided on the optical path between the light receiving element and the clearance forming member is formed by a hole.

3. The optical sensor according to claim **1**, wherein

the light emitting element and the light receiving element are accommodated in the support member at a position opposite to the clearance forming member.

4. The optical sensor according to claim **3**, wherein

the first reflection surface and the second reflection surface are rectangular prisms having reflection surfaces for bending the optical path, and

the fluid clearance is formed between the two rectangular prisms.

5. The optical sensor according to claim **1**, wherein

a width of a space on the optical path between the light emitting element and the clearance forming member at a side of the clearance forming member is shorter than a width of the space at a side of the light emitting element, and

the optical path between the light emitting element and the clearance forming member and the optical path between the light receiving element and the clearance forming member extend in a direction in which the optical sensor is inserted to the mating member.

6. The optical sensor according to claim **4**, wherein

a groove surrounding an opening of a space on the optical path between the light emitting element and the clearance forming member is formed on a surface of the support member to which the clearance forming member is attached.

7. An optical sensor, comprising:

a light emitting element that emits a light;

a light receiving element that detects the light;

a transmissive part that includes an incident surface to which the light is incident from the light emitting element and an exit surface from which the light incident on the incident surface exits, and defines a gap, into which a lubricant enters, in an optical path from the incident surface to the exit surface; and

a first narrowing part that narrows the optical path from the light emitting element to the incident surface.

8. The optical sensor according to claim **7**, wherein

the first narrowing part includes:

a first part defining a first hole in which the light emitting element is accommodated; and

a second part defining a second hole which communicates the first hole with the incident surface and has a first narrowed portion, and

an area of the optical path in the first narrowed portion is smaller than an area of the optical path in the first hole.

9. The optical sensor according to claim **7**, further comprising

a second narrowing part that narrows the optical path from the exit surface to the light receiving element.

10. The optical sensor according to claim **9**, wherein

the second narrowing part includes:

a third part defining a third hole in which the light receiving element is accommodated; and

a fourth part defining a fourth hole which communicates the third hole with the exit surface and has a second narrowed portion, and

an area of the optical path in the second narrowed portion.

11. The optical sensor according to claim **7**, wherein

the transmissive part includes a first rectangular prism and a second rectangular prism,

the first rectangular prism has:

a first incident surface which is the incident surface;

a first exit surface orthogonal to the first incident surface;

a first reflection surface which is an inclined surface with respect to an apex angle being right angle and which bends the optical path of the light incident on the first incident surface;

a pair of first side surfaces which sandwich the first incident surface, the first exit surface and the first reflection surface,

the second rectangular prism has:

a second incident surface which opposes the first exit surface;

a second exit surface which is orthogonal to the second incident surface and which is the exit surface;

a second reflection surface which is an inclined surface with respect to an apex angle being right angle and which bends the optical path of the light incident on the second incident surface;

a pair of second side surfaces which sandwich the second incident surface, the second exit surface and the second reflection surface,

at least one of the first rectangular prism and the second rectangular prism is an object to be fixed, and

the optical sensor includes a wall to which a surface including the side surfaces is fixed, in the object to be fixed.

12. The optical sensor according to claim **7**, further comprising:

a supporting member which supports the light emitting element, the light receiving element and the transmissive part, and

the supporting member includes the first narrowing part.

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